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14. ABSTRACT

Research and development of novel evaluative methods for proton beam radiotherapy is the primary research presented in this annual report. The long-term objective of this research was to develop a methodology for integrating as well as knowledge discovery of a DICOM-Radiation Therapy electronic patient record (ePR) system to manage patients with most types of Proton Beam Therapy (PT) treatment cases across multiple sites with DOD patients. As a first step, de-identified data samples from patients treated with PT at Loma Linda University Medical Center (LLUMC) was utilized for proof of concept for the research design, implementation, and evaluation. A prototype DICOM-based RT ePR Information System integrating all necessary RT related data and images was designed and presented at a Proton Therapy symposium. The objectives of the research focused on patient cases treated by PT at LLUMC because of the proximity and collaborative efforts between our research laboratory and LLUMC. The success of this proposal has tremendous impact to the US Military healthcare service, specifically in two parts: 1) Integration of clinical data obtained from PT clinical sites with DOD patients that can be distributed globally to local peacetime stationary hospitals and clinics of cancer patients for tele-consultation and managed care. 2) Provide an infrastructure to perform large-scale horizontal and longitudinal outcome studies to improve clinical efficacy and efficiency to the patient.

15. SUBJECT TERMS
Proton Therapy, Medical Imaging Informatics, DICOM-RT-ION, Electronic Patient Record (Epr)

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Table of Contents

Introduction……..4

Body……6

Key Research Accomplishments……21

Reportable Outcomes……22

Conclusions……23

References……

Appendices.....

Introduction

Over the past several years the expansion of the portfolio of the Telemedicine and Advanced Technology Research Center (TATRC) managed research projects has led to significant achievements in support of the goals of the U.S. Army Medical Research and Materiel Command (USAMRMC). While this expansion has served to distribute TATRC investments both nationally and internationally, the ability to effectively leverage and bring together assets, expertise, and capabilities in the western United States to develop new, cutting-edge advanced technology research and development efforts has been taxed. This award offers a unique opportunity for the TATRC to further revolutionize military medical research in support of training and readiness, medical Command and Control, and employment of medical forces across the Department of Defense (DOD) through collaboration with the Henry M. Jackson Foundation for the Advancement of Military medicine, Inc. (HJF) in establishing the infrastructure and initial research efforts of a Western Pacific regional research center.

To accomplish the above goals, five (5) original objectives were proposed in the form of tasks. Task 1 is the primary Task with Task 2-5 as auxiliary tasks. Task 5 was submitted as a completed task in last year's annual report.

Task 1: Research and development of novel evaluative methods for proton beam radiotherapy using the ongoing and emerging work in two HJF/TATRC proton beam centers.

Proton Beam Therapy: Evaluative Mechanisms. Phase I of this task was subawarded to the University of Southern California with Dr. Brent Liu as the Principal Investigatory.

Phase I Tasks include:

Objective: 1.5 Months
1. General Workflow Modeling for Cancer Patients Treated w/ PT at LLUMC including 3 sub-tasks:
1.1 General Survey of the Clinical Operations and Data workflow of PT of patients at LLUMC
1.2 Scope Analysis and Identification of Sub-Category of Cancer Type Treated w/ PT
1.3 Refined Clinical Workflow Model for Specific Cancer Type Treated w/ PT

Objective 2: 2.5 Months
2. Development of Data Models including 4 Sub-tasks:

2.1 Clinical Data Survey of Cancer Patients treated at LLUMC PT site from the PT Treatment Planning System and ancillary clinical info systems.
2.2 Customizing DICOM-RT data models to standardize PT data
2.3 Integration of Imaging-Related Data Types (eg, PACS studies, RT images, structure, dose, reports) within the Data Model Design/Architecture
2.4 Refinement of the Data Model Design/Architecture

Objective 3: 2 Months
3. Design and Development of the integrated ePR System with DICOM-RT objects including 3 sub-tasks:
3.1 GUI design and development based on Clinical Workflow Model and Data Model developed in tasks 1 & 2
3.2 Database design and development based on Task 2
3.3 Hardware specifications and design for overall system

Objective 4: Attend the October 18-20, 2006 Symposium "Developing and Understanding a Hospital Based Proton Facility" and present initial results.

Task 2: Identification of novel research programs leveraging regional investments.

Task 3: Create a dynamic process through which to transition selected technologies from advanced research to advanced development.

Task 4: Establish the infrastructure (physical and personnel) of the TATRC Western Field Office/Research Center in such a way as to institute the means of close interaction between USAMRMC/TATRC research managers and their Principal Investigators located in the Western US and Pacific Rim

Task 5: Establish administrative support.

Body of Annual Report

Task 1: Research and development of novel evaluative methods for proton beam radiotherapy using the ongoing and emerging work in two HJF/TATRC proton beam centers.

Proton Beam Therapy: Evaluative Mechanisms.

Research Objectives:

The long-term objective is to develop a methodology for integrating as well as knowledge discovery of a DICOM-Radiation Therapy electronic patient record (ePR) system to manage patients with most types of Proton Beam Therapy (PT) treatment cases across multiple sites with DOD patients. As a first step, the development will be based on utilizing patients treated with PT at Loma Linda University Medical Center (LLUMC) for proof of concept for the research design, implementation, and evaluation. A prototype DICOM-based ePR Information System integrating all necessary PT related data and images will be researched. The objectives will be focused on patient cases treated by PT at LLUMC because of the proximity and collaborative efforts between our research laboratory and LLUMC. The success of this proposal will have tremendous impact to the US Military healthcare service, specifically in two parts: 1) Integrate clinical data obtained from PT clinical sites with DOD patients and distribute globally to local peacetime stationary hospitals and clinics of cancer patients for tele-consultation and managed care. 2) Provide an infrastructure to perform large-scale horizontal and longitudinal outcome studies to improve clinical efficacy and efficiency to the patient.

Introduction:

Proton Beam Therapy (PT) is a particular treatment that utilizes energized charged particles, protons, to deliver dose to the target region. Protons are energized to specific velocities which determine where they will deposit maximum energy within the body to destroy cancerous cells, allowing for maximum dose to the target region while minimizing dose to surrounding tissues. This is due to the fact that the Proton Depth Dose (Bragg Peak) is inversely proportional to the square of the particle velocity. In comparison, Photon Depth Dose is proportional to an exponential function. Figure 1 shows a comparison between 6MV Photons from a Linear Accelerator utilized in traditional radiation therapy and different energy Protons. Each of the different energy protons have minimal dose in water but deposit their maximum dose at a target depth. This translates to less dose to normal healthy tissue in the body while depositing most of the energy within the target tumor located at a certain depth within the body. In addition, proton beams have no exit dose which also minimizes damage to health tissue beyond the target tumor. Proton Therapy is especially effective for types of cancer that require controlled high concentration dose and tumors that are close to sensitive tissue. Some examples of the types of cancer treated include: Prostate, Brain, Spinal Cord, Head and Neck, Base of Skull, Eye, Lung, and tumors in children.

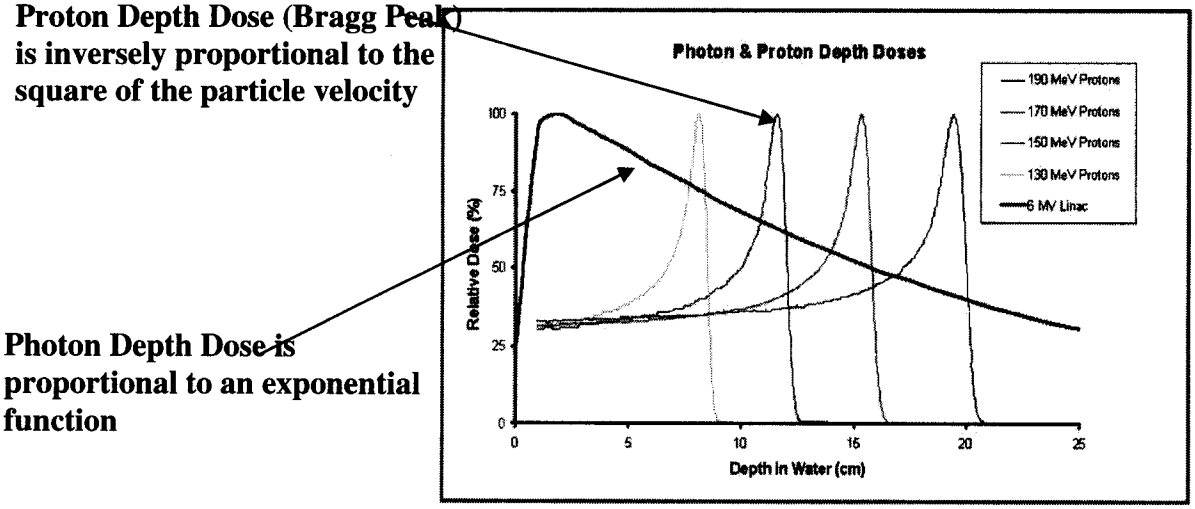

Figure 1: Graph showing a comparison between Photon Depth Dose (6MV) and Proton Depth Dose (130, 150, 170, 190 MeV) percentages as measured in water. The maximum dose from the proton can be deposited at a certain depth. This can be utilized to treat cancer tumors at a certain depth while minimizing dose to surrounding normal health tissue.

Similar to traditional Radiation Therapy (RT), complex clinical imaging and informatics data are generated during the treatment process that guide the planning and the success of the treatment. In addition, there are few PT sites across the country due to the complex and expensive system requirements which include a synchrotron, linear accelerator, and large rotating gantry and require a very large square area footprint. Loma Linda University Medical Center (LLUMC) was the first to open a clinical PT treatment center and began treating patients starting October 1990. There are now facilities in Bloomington, IN; Boston, MA; with emerging sites in Houston, TX and the East coast, as well as established international sites. The need for a standardized and centralized clinical data repository and integrated system with proper data distribution to manage cancer patients becomes crucial. Distances between PT sites and the proprietary nature of vender-of-choice between PT sites will undoubtedly lead to a similar fate as the fractured industry market in RT. Therefore, initiating this integrated system for PT is not only timely, but urgent in order to prevent this. In addition, as new PT facilities come online, global distribution of standardized data for information sharing of best practice can impact a greater adoption of this type of treatment for cancer patients. An integrated system of standardized data can serve as the mandate for future PT sites and drive the industry, ultimately reducing costs, improving clinical efficiency, and patient outcomes.

This report presents the initial results towards extending the medical imaging informatics methodology to develop decision-support knowledge for managing cancer patients treated with PT. Research collaboration was established with LLUMC to develop the first prototype system. To date, over 45,000 patients have been treated with PT, of which 11,562 patients were treated at LLUMC. Of the types of cancer treated, 65% were male

patients with prostate cancer, which represents the largest population of patients treated with PT anywhere in the world. Currently, LLUMC is treating approximately 50 to 170 patients per day making the center one of the most efficient PT facilities nationwide. We have extended our knowledge-based imaging informatics methodology for cancer patients treated with PT, and researched and designed a prototype system and infrastructure platform for future development of the knowledge base as well as decision-support tools that can be add-on features to a standards-based ePR system for sharing of best practice data. Various generic information/management systems feature the availability of necessary clinical data within the RT department. However, the most complete clinical data model is from the proposed standards-based ePR system of this research. Furthermore, the ePR system features open system integration based on the DICOM standard instead of proprietary like other RT information/management systems. In summary, the ePR system has the following superior features:

1) Complies with DICOM-RT and DICOM-RT-ION Object definitions.
2) Global data distribution.
3) Global Treatment Updates.
4) Open System Integration.

Development and Results for Ojective 1: General Workflow Modeling for Cancer Patients Treated w/ PT at LLUMC

Medical Imaging Informatics Research Methodology

Figure 2 shows a summary of the research methodology for standardizing PT data objects and performing Medical Imaging and Informatics research to develop the knowledge base, the data mining, and quantification and visualization tools which ultimately become add-on features to the standard-based ePR system. With these decision-support tools, the end result is that clinicians can be assisted in their decision-making process for new cancer patient cases. This research methodology can be applied to different lesion types as well as treatment types to quickly research and develop new decision-support tools.

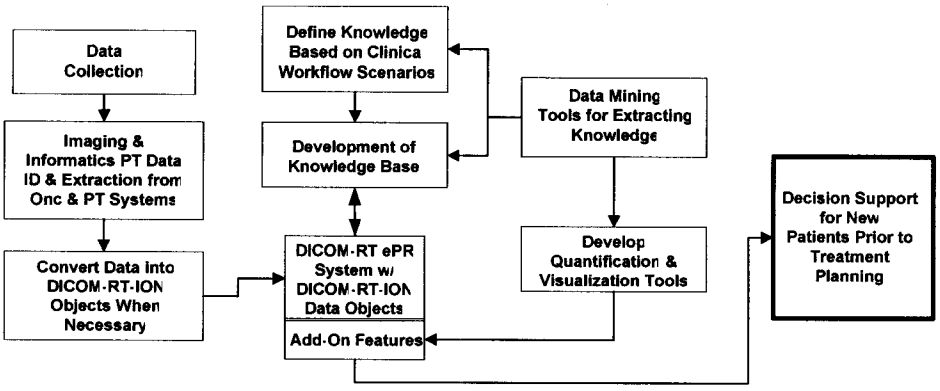

Figure 2: A Medical Imaging Informatics approach towards development of decision-

support tools for the DICOM-RT based ePR system. The final results are add-on features for the ePR system to provide decision-support for new patient cases. This methodology can be applied to different lesion types as well as treatment types to quickly research and develop new decision-support tools.

Workflow Model for Proton Therapy (PT) of Cancer Patients

One of the most important first steps for system integration of clinical image and information systems is to research the workflow model of the clinical operations. Since the focus of this research will be on patients treated with PT, the workflow related to these particular treatment cases will be studied. A general clinical workflow model for PT was developed for LLUMC as shown in Figure 3.

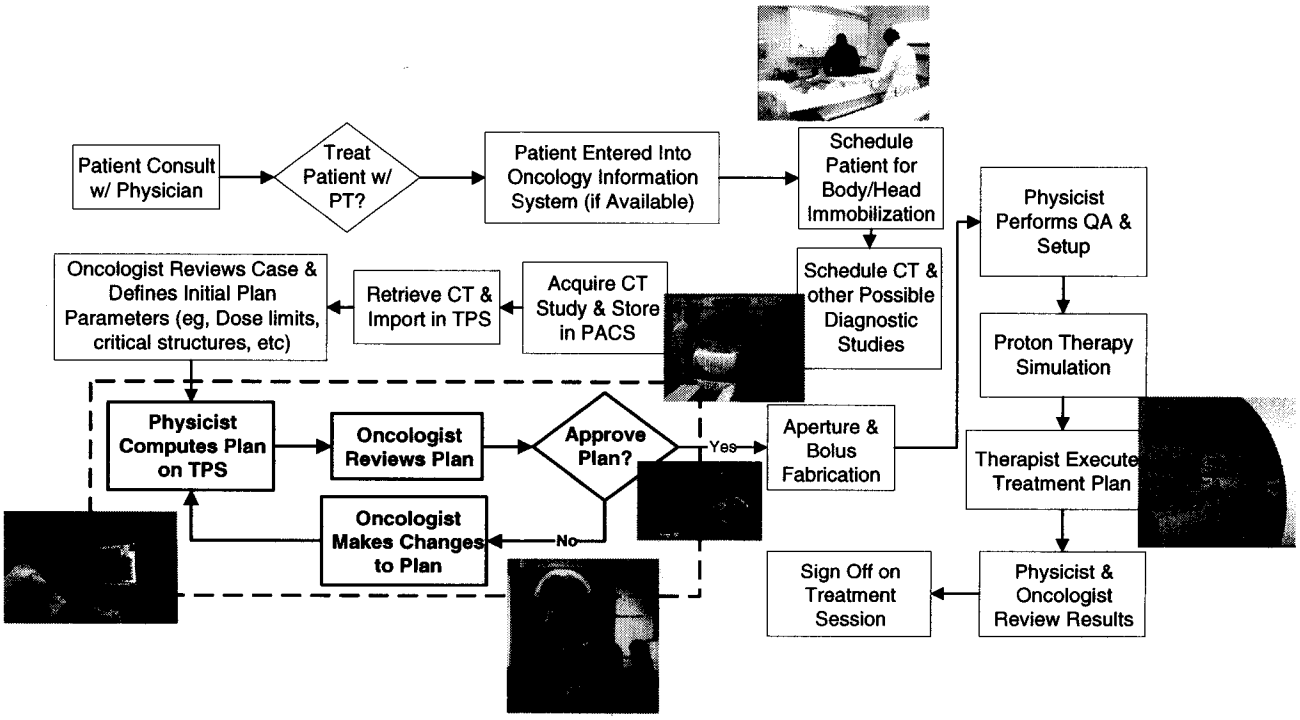

Figure 3: General Clinical Workflow for PT of Cancer Patients.

The treatment begins with the patient diagnosed with cancer lesion or multiple lesions. The patient consults with the physician(s) and determines whether to treat the tumor(s) and whether PT will be performed. The patient is entered in an oncology information system and is scheduled for treatment if the system is available, otherwise the scheduling is performed on a paper-based system. Next, the patient is scheduled for body immobilization or head immobilization. If the treatment is to be performed for the brain or head and neck, a head cage made of lightweight plastic is cast to immobilize the head during the CT scan and the actual treatment. If the body is to be immobilized, then a plastic cradle is utilized with injected foam cushioning to immobilize the body for imaging, planning, and treatment. A diagnostic CT will be acquired to plan the treatment based on the patient being immobilized. In addition, other imaging may be acquired, such as PET or MRI to help better define the cancer to be treated. Most of the time, a CT

study is adequate for treatment planning. The Radiologist and Radiation Oncologist review the patient's case and then the Radiation Oncologist defines the initial plan parameters such as dose limits and constraints, critical structures, and tumor volume to be treated. The physics team then computes the plan based on these dose constraints on the corresponding TPS. Once the initial plan is computed, the Oncologist reviews the results and makes any necessary changes. This process can be iterative and the feedback loop is defined in Figure 4 by a dashed line region similar to traditional Intensity-Modulated Radiation Therapy (IMRT). Once the treatment plan has been approved, the data is used to build a 3D computer assisted bolus made of high-grade wax and apertures made from an alloy called cerrobend that will shape the proton beam for treatment of the target tumor(s). QA and setup is performed and a simulated treatment plan will be executed in order to make any fine-tuned adjustments to the overall plan. The PT session is then executed by the Radiation Therapist within the gantry and the corresponding PT plan data are stored in the treatment planning systems and some results are also inputted into the oncology information system or a Record and Verify system. Since there are a variety of tumor types, the treatment paths can differ. Therefore, it is important to research and develop a more robust workflow model that can accommodate the various treatment paths and identify points within the workflow that can be improved. Not only would this enhance the design of the DICOM-based ePR System, but also serve as the foundation for a methodology to build quantification and visualization tools for decision-support. In this case, the iterative feedback loop is identified as a potential area of improvement. The feedback loop represents the inverse treatment planning process and can be quite tedious if much iteration is necessary. This becomes the area of focus where decision-support tools may benefit during the decision-making. If more *a priori* knowledge and robust quantification and visualization tools can be included during the decision-making process of the initial plan parameters, then it is possible to reduce the iterative process.

Development and Results for Objective 2: Research and Development of Data Models

The DICOM (Digital Communication in Medicine) standard has been well established and widely successful for clinical imaging systems in Radiology, in particular PACS (Picture Archiving and Communication System). Image data acquired from equipment from different vendors can readily communicate with each other and integrate into a system through the DICOM standard. In 1997, the DICOM standard was extended to include radiotherapy information and further updated in the latest version released in 2003. Seven DICOM radiotherapy (DICOM-RT) objects have been included by the DICOM standards committee for transmission and storage of radiotherapy images and related information. These DICOM-RT objects are: 1) RT Image, 2) RT Plan, 3) RT Structure Set, 4) RT Dose, 5) RT Treatment Record, 6) RT Brachy Treatment Record, and 7) RT Summary Record. In March 2006, supplement 102 was finalized to include two additional RT objects for Ion Therapy applications which include PT. These two objects include RT ION Plan and RT ION Treatment Record. These two additional objects refer to the same RT Objects: RT Image, RT Dose, and RT Structure Set. Figure 4 shows the DICOM model of the real world showing where the Radiotherapy Objects reside. Figure 5 shows in greater detail how the DICOM-RT-ION objects are added to

the overall set of Radiotherapy Objects. Generally, the sources for these data come from treatment planning systems (TPS), oncology information systems, and PT systems. TheDICOM-RT-ION object information models can be utilized to develop the data structureand database schema for the electronic patient record. To develop a conceptual data model, the PT workflow must be reviewed to define the data required. Additionally, clinical user input is needed as well. With these input sources, a conceptual model can be developed for a PT electronic patient record.

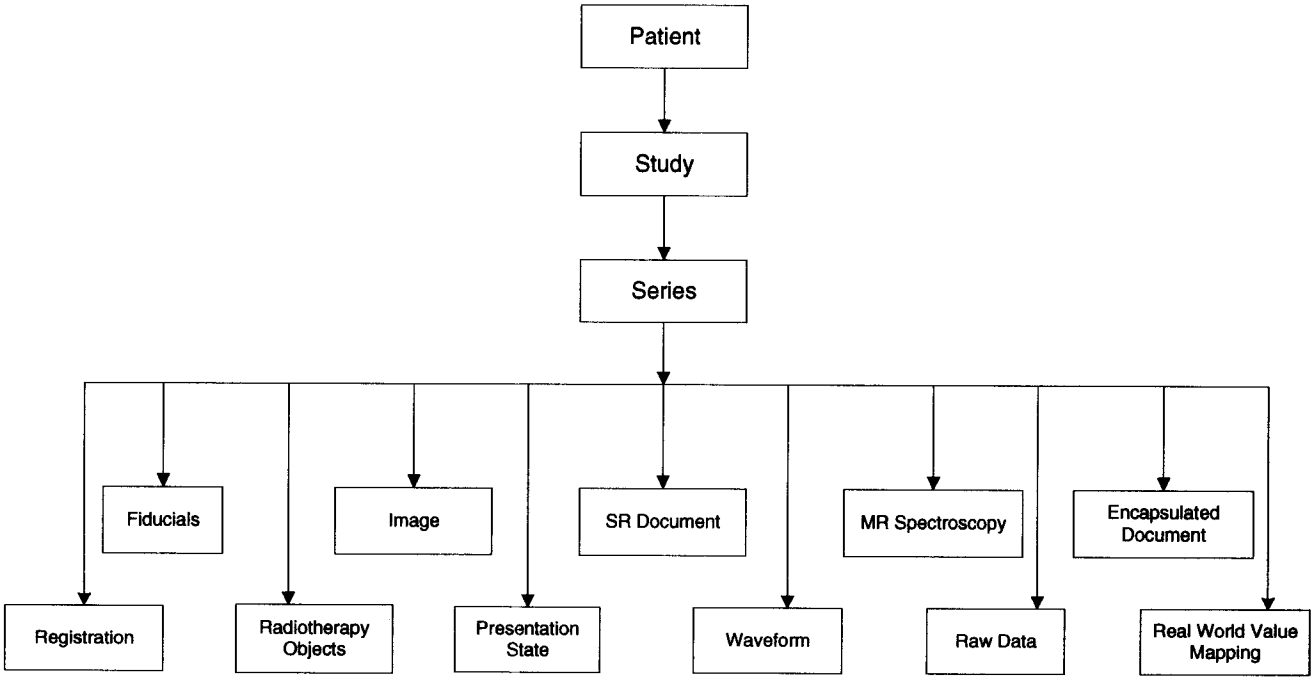

Figure 4: Portion of the DICOM Model of the Real World showing where the Radiotherapy Objects reside.

An initial data survey was performed to track patient cases utilizing the clinical information systems at LLUMC. Two types of patient cases of brain and prostate tumors were tracked to determine the treatment path and outcome. The two cancer types were chosen since they represent complex treatment planning cases with surrounding critical structures that require controlled dose to the target tumor while limiting dose to normal and healthy tissue. These results were implemented into the clinical workflow model. The preliminary data collection survey was performed to determine the feasibility of data collection at LLUMC as well as to assist in the development and design of both the database schema as well as the overall ePR system design architecture. The brief survey was performed using clinical information systems to track historical patients and their record and was performed under the HIPAA Regulations and Compliance Guidelines set forth by LLUMC.

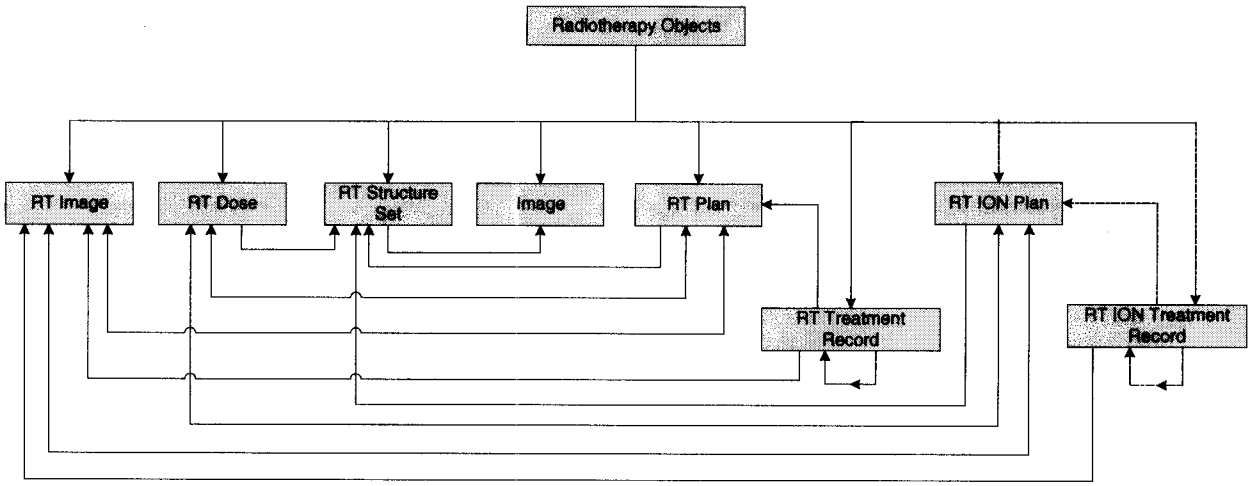

Figure 5: Portion of the DICOM model of the Real World showing the extension of the two RT-ION objects. Note: The two ION objects, RT-ION Plan and RT-ION Treatment Record, refer to the same RT objects as the two RT Objects, RT Plan and RT Treatment Record.

Figure 6 shows a portion of the results of the database schema design for the ePR system. The database schema framework was developed based on the DICOM-RT and DICOM-RT-ION standards mentioned before to insure full interoperability of the data as well as compliance to already established de-facto standards. The design of this database schema is robust, flexible, and extensible to accommodate new DICOM related objects as needed and extension of the database to include the knowledge base and related metadata (eg, outcomes results of PT gathered by LLUMC on a per patient basis) in future research development.

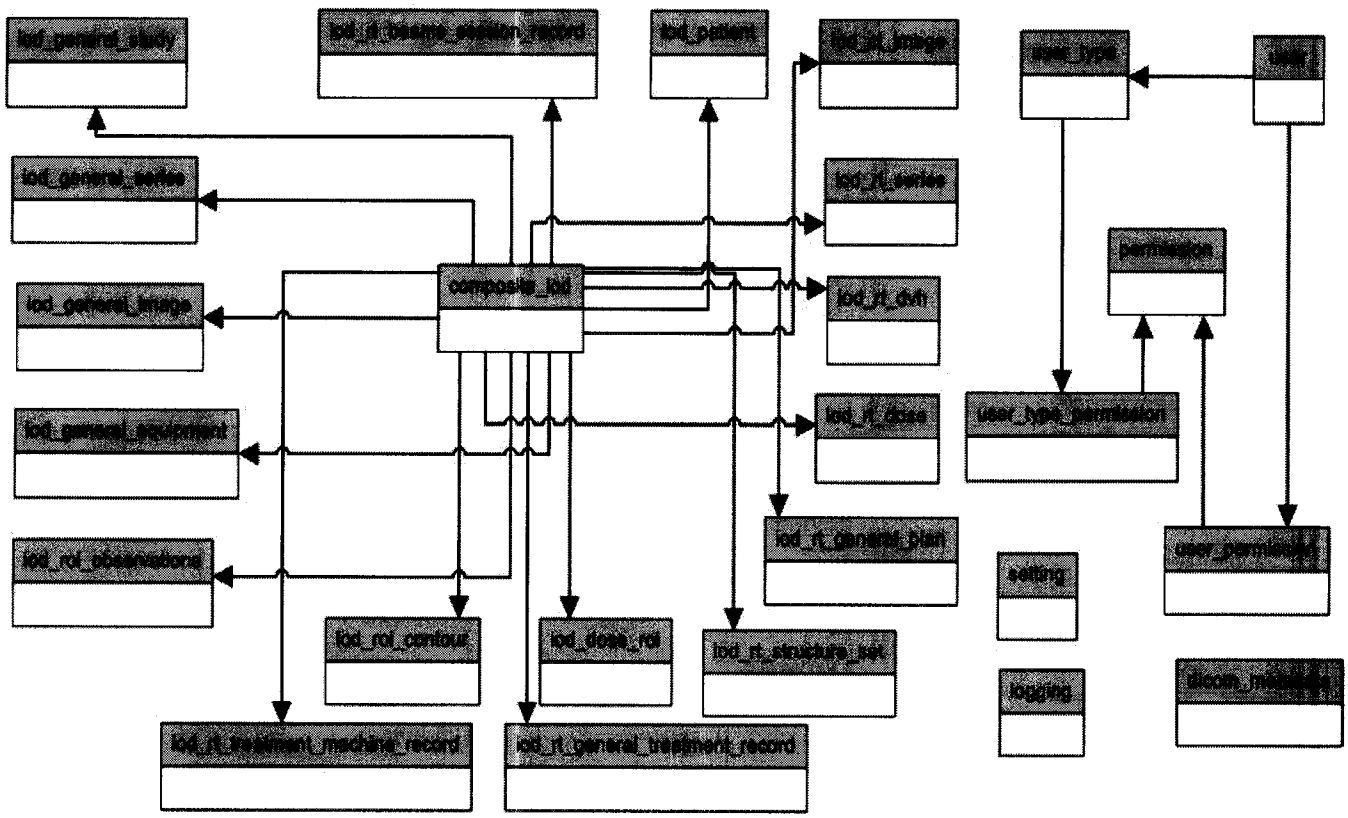

Figure 6: Portion of the Database Schema for the ePR system. Data objects are based on the de facto DICOM-RT and DICOM-RT-ION standards. The database schema can also accommodate the knowledge base as well as related metadata to enhance the overall ePR system in future research development.

Development and Results for Ojective 3: Design and Development of the integrated ePR System with DICOM-RT objects

Based on the clinical and data workflow models, Figure 7 shows the overall ePR system architecture design. The system architecture allows for the greatest flexibility while allowing future development. Global distribution of key imaging and informatics data and future knowledge base and data mining tools are accomplished with a web-based design. Tools to mine the database and well as quantifying knowledge can be developed in a modular approach without impacting the overall system and eliminating the need to redesign in the future.

The main goal of the ePR architecture is to be standards-oriented, portable, scalable and at the same time flexible. In order to achieve this we utilized libraries, modules, servers and programming languages that are either open source or publicly available. In some cases, due to the specific requirements of the ePR we have made some changes to those libraries to fulfill those requirements. The utilization of modules or plug-ins provides a rich mechanism to extend the ePR according to any future needs, without losing the robustness for the core tasks handled by the ePR framework. The following are a list of some of the current libraries and OS utilized:

- Windows OS
- DICOM receiver: dcmtk open source library
- ePR Framework: php5, with pear and gd package installed
- DICOM module: php5 (using php-DICOM module 0.3)
- DB module: php5 (with connection to mysql 5 database)
- Additional modules: php5 with necessary wrappers for other programming languages
- Web server: apache2 open source

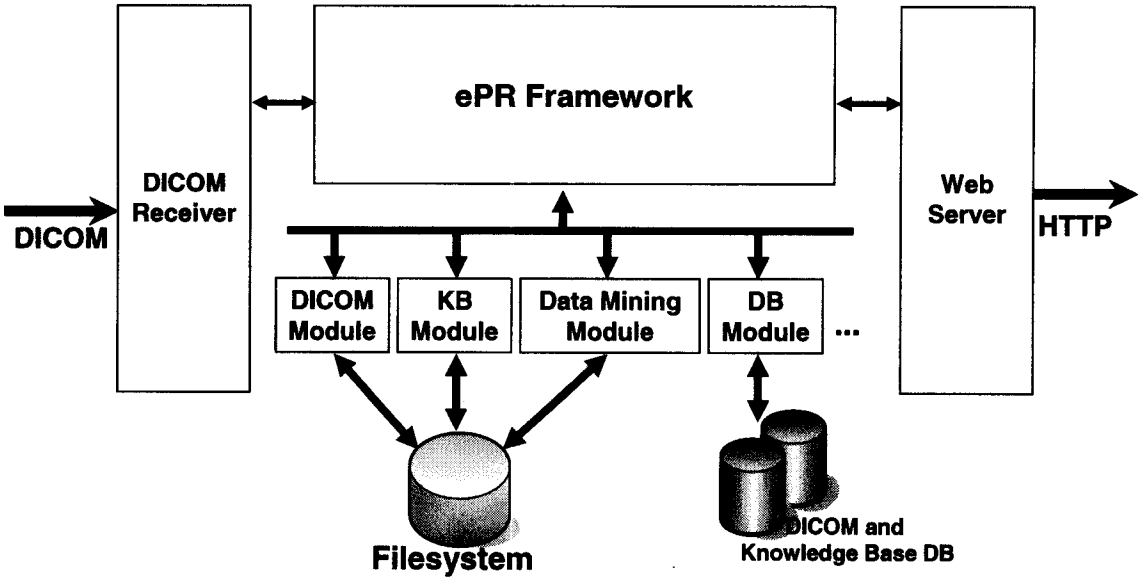

Figure 7: The DICOM-based ePR System Architecture

Figures 8 and 9 show the Data Workflow for collecting the Proton Therapy Imaging and Informatics data. The system was designed to import and integrate both data objects that are already in the DICOM-RT and DICOM-RT-ION format as well as proprietary data objects which will subsequently by converted into DICOM-compliant data objects.

The following workflow steps for integrating DICOM objects are as follows:

- Step 1: DICOM data objects are sent utilizing the DICOM standard through the DICOM receiver.
- Step 2: The DICOM objects are stored in a temporary folder awaiting extraction.
- Step 3: Key DICOM information are extracted from the data objects.
- Step 4: DICOM information is saved into the database while the image data files are stored locally in the file system.

The following workflow steps for integrating non-DICOM and proprietary data objects are as follows:

- Step 1: non-DICOM objects and proprietary data are transferred utilizing the Web Interface.
- Step 2: non-DICOM objects are stored in a temporary folder awaiting extraction.

- Step 3: Conversion of non-DICOM objects into DICOM-compliant data objects are performed utilizing the DICOM conversion module.
- Step 4: Key DICOM information are extracted from the data objects.
- Step 5: DICOM information is saved into the database while the image data files are stored locally in the file system.

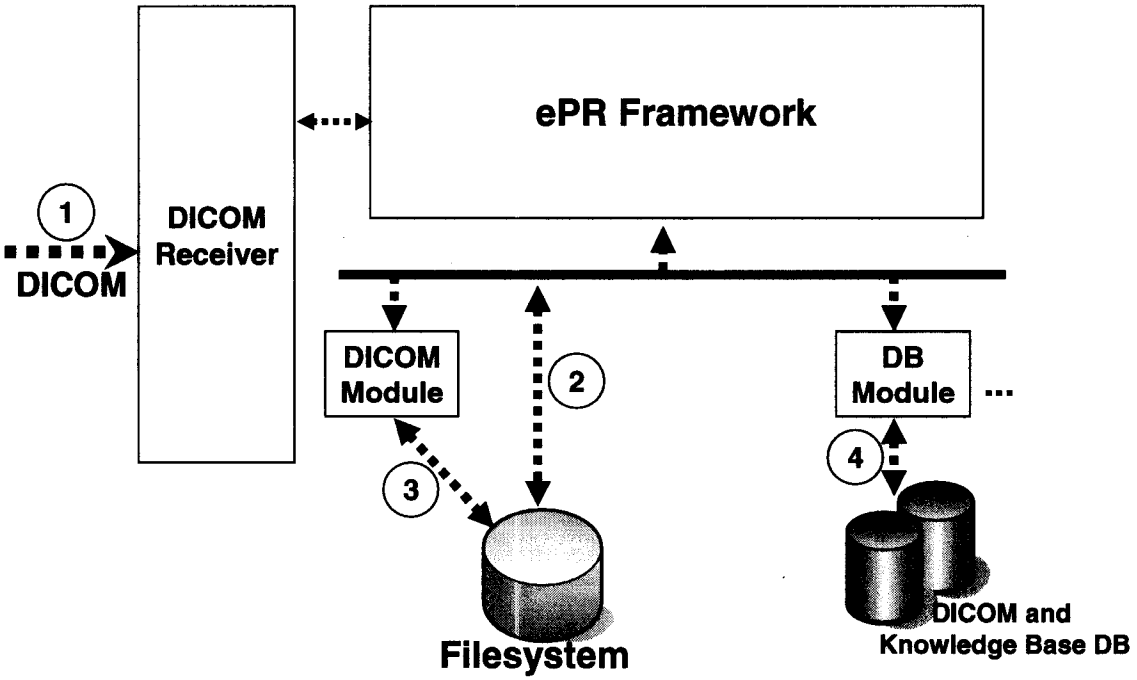

Figure 8: Data Workflow diagram for integrating DICOM-compliant data objects with the ePR system. The detailed workflow steps are described above.

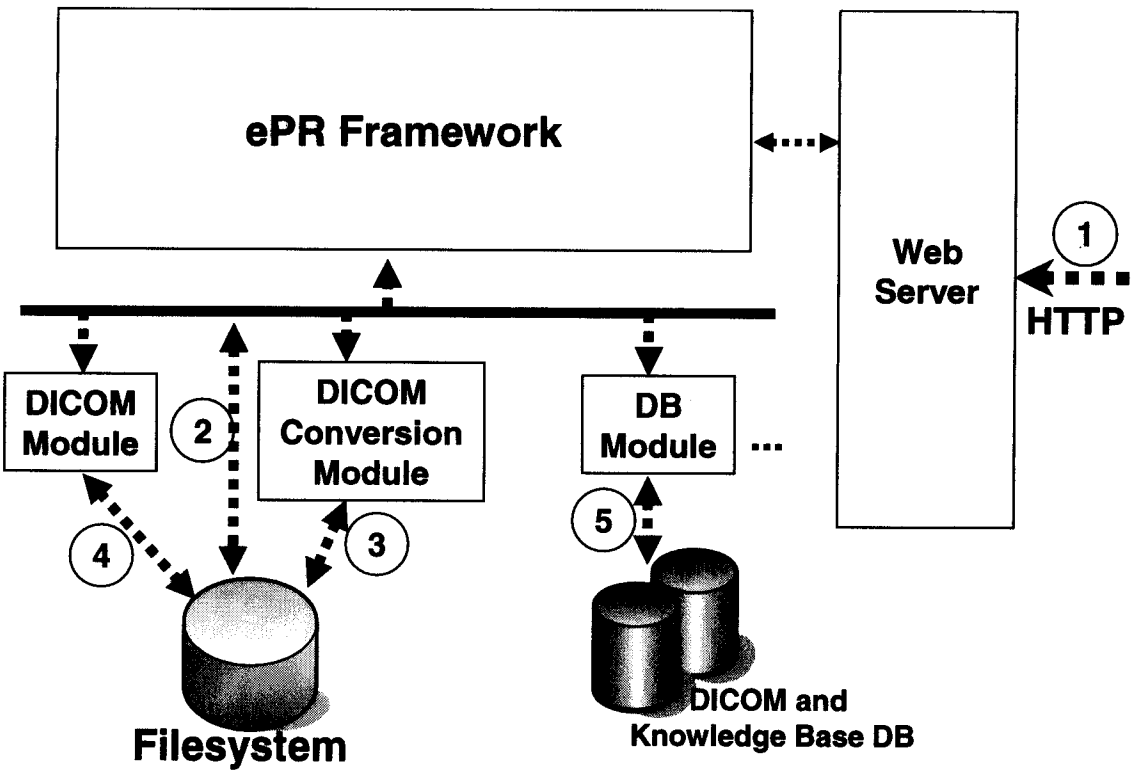

Figure 9: Data Workflow diagram for integrating non-DICOM and proprietary data objects with the ePR system. The detailed workflow steps are described above.

In future research development, the knowledge base along with data mining tools can be integrated within the ePR system architecture. Furthermore, key metadata such as outcomes results of PT for a particular treatment plan can be integrated as well. This will form the basis of a standards-oriented, open architecture system to perform large-scale horizontal and longitudinal outcome studies to improve clinical efficacy and efficiency to the patient and sharing of best practice data to future adopters of PT.

Development and Results for Objective 4: Attend the October 18-20, 2006 Symposium "Developing and Understanding a Hospital Based Proton Facility" and present initial results.

Initial results were successfully presented at the October Symposium. As a result, a paper has been generated summarizing the results of the presentation and has been accepted and submitted for publication in the Journal of Technology in Cancer Research and Treatment. In addition, the results of this one year research was presented at an international Medical Imaging conference (SPIE Medical Imaging Conference, San Diego) and published in a proceedings manuscript. Furthermore, initial work was also published in part within a second peer-reviewed journal, Computerized Medical Imaging and Graphics.

Task 2: Identification of novel research programs leveraging regional investments.

Research Objective:
Help develop new, leading- edge research and development initiatives (e.g. embedded training, "next generation" far- forward trauma care, etc.) in the western US, including facilitating creation of working relationships with nationally unique assets found only in the Pacific/West region (e.g. University of Southern California's Institute of Creative Technology, DARPA, etc.). Perform critical tasks and provide support as deemed necessary for new R&D portfolio/program implementation and as requested by USAMRMC/TATRC.

Accomplishments:

We found that projects located in the Western US region were not being managed as effectively as projects closer to headquarters office located in Ft Detrick, MD. The physical distance, time difference and personnel availability were the biggest factors that hindered proper management of these projects. Located in Marina Del Rey, CA, TATRC West is in a prime location to manage regionally located programs with greater efficiency and creates novel opportunities to partner with the entertainment, video game and the booming medical device industry as well as other DoD funded research centers. The office is an extension of the headquarters and expanded TATRCs capability to oversee the project progress. TATRC can now meet with regionally located PIs with greater ease to discuss project status, address issues and guide them to various offices under USAMRMC.

Currently funded institutions that benefit from the west coast presence:

- UCLA Center for Advanced Surgical and Interventional Technology
- UCSD
- Loma Linda University Medical Center
- University of Oregon Brain Biology and Machine Initiative
- Loma Linda VA Hospital Musculoskeletal Disease Center
- Apogen Technologies, Inc
- University of Texas Health Sciences Center
- Multi-Dimensional Imaging, Inc
- University of Hawaii – Advanced Studies in Genomics, Proteomics and Bioinformatics Center
- Baylor College of Medicine
- MD Anderson Cancer Center
- Rice University
- Health Officers Association of California

Hosted/Participated in various regional meetings/conferences/symposia, as consistent with TATRC's regional (programmatic, research management, and partnership-building) agenda and mandate. Examples include putting on various Product Line Reviews and assisted in Medicine Meet Virtual Reality (MMVR) Conference.

Continued to explore, develop/cultivate new strategic relationships/partnerships with regional academic and commercial organizations and activities (e.g. University of CA-Santa Barbara, Naval Health Research Center, etc.).

During this period work continued on the development of the Medical Logistics Research portfolio at TATRC guided by the TATRC Medical Logistics IRT (Integrated Research Team) held in 2005. Efforts also continued to build relationships and collaborations within the DoD, with other governmental agencies and with industry to further R&D efforts that will advance the execution of medical logistics by the application of emerging technologies. A strong collaborative relationship has already been forged with Navy Medicine and the Navy AIT Office and efforts are being made to foster a similar relationship with the Air Force

TATRC was represented at Meetings of the Medical Logistics Proponency Committee (MLPC), the Joint Enterprise Wide Logistics-Medical IPT (JEWL-M IPT), and the RFID Working Group, and a number of other groups, both government and non-government, to discuss many aspects of medical logistics, including Hospital of the Future implications.

Two medical logistics related STTR three SBIR topics were prepared and managed. During this period proposals for these topics were evaluated and recommendations made. Discussions have continued with the Strategic Mobility 21 effort in the Long Beach, CA area. A collaborative effort with Strategic Mobility 21 has been proposed and is currently being evaluated.

Work on an RFID Asset Tracking demonstration project at TATRC was begun. The primary purpose of this research project is the development of a system to track and manage medical equipment in deployed medical facilities. The TATRC OASIS platform is being used for this proof of concept effort. Initial results are very promising and expansion of the project is anticipated.

The most significant accomplishment during this period was the conceptualization, planning and execution, with the support of the Penn State University Center for Supply Chain Research, of a conference entitled "Automatic Identification Technology in Defense Medical Logistics". This one day conference, held in Frederick, MD, was attended by more than sixty leaders in medical logistics from each of the services, a number of DoD offices, other agencies, including the FDA and industry. A demonstration of the Asset Tracking Proof of Concept at the TATRC OASIS site was a part of the conference.

Task 3: Create a dynamic process through which to transition selected technologies from advanced research to advanced development.

Research Objective:
Task three (3) will seek to create a dynamic process through which to transition selected technologies from advanced research to advanced development. Specific goals of task 3 include: identify products in the existing (TATRC regional) portfolio that are candidates for transition to advanced development; encourage, and facilitate (regional) development of prototypes, prototype demonstrations, and (prototype) field trials; conduct aggressive (regional) technology surveillance; develop a robust, productive mix of partnerships with (regional) firms for the purposes of rapidly identifying and prototyping key and enabling technologies as required by the "Joint Warfighter" and civilian emergency medical and military medical service agencies; and, evaluate the impact of government intellectual property (IP) development and technology transfer.

Accomplishments:
As a member of the Southern California Biomedical Council (SCBC), an industry association whose mission is to promote biomedical research and manufacturing in Southern California, we are exposed to other members that are developing medical devices. Working with Dave Hood, Sr Advisor to MRMC, have participated in numerous industry meetings within California to track medical device development that have potential military application. We are also looking into additional industry associations such as Medtech Insight, OCTANe and Link that have the same purpose.

The TATRC West office continued its efforts of expanding research and development interests in the Pacific Rim. TATRC-West personnel, in a business development role, dealt with individual proposals and prescribed courses of action for the research community both in and around the Los Angeles area. Specifically, the following contracts and issues were items of interest during the tenure of this reporting period:

- W23RYX-7967-N603 requests the award of a multi million dollar research project for the conduct of research at the University of California, Los Angeles. The issue was principally one of eliciting the public purpose of the work to support the award documentation in USAMRAA.

- An award to the Regents of the University of California at Santa Barbara, "Novel Materials, Signal Processing, and Image Reconstruction Techniques for Flexible Conformable Ultrasound Arrays" $196,032.00. Issues dealt with indirect rate recovery and how this award related to the Institute for Collaborative Biotechnologies.

- DAMD17-03-2-0061 to the Foundation. Issue: the relationship of SF272 – Quarterly Financial Reports, specifically how do the financial reporting terms and conditions reconcile with the technical reporting terms and conditions.

Attendance at the 2007 American Telemedicne Association conference also provided person to person contact with some of the staff of the TATRC West. It also afforded ample opportunity to follow ongoing research interests as well as to discuss potential future research projects with other interested organizations and institutions. Highlights of the ATA Conference included:

- A meeting with Wound Technology Network to discuss an existing methodology of wound treatment particularly on how to approach the AMEDD with a research effort aimed at advanced this project toward a more useable, field-able product. (The ATA session was followed by a subsequent meeting in Washington, DC
- Roundtable Discussion programs focusing on the subject arenas of "Busies and Finance, Operations and Policy"
- Numerous Concurrent Panel Discussions
- Booth side discussions with many of the vendors on the convention floor

Task 4: Establish the infrastructure (physical and personnel) of the TATRC Western Field Office/Research Center in such a way as to institute the means of close interaction between USAMRMC/TATRC research managers and their Principal Investigators located in the Western US and Pacific Rim

Research Objective:
Task four is to establish the infrastructure (physical and personnel) of the TATRC Western Field Office/Research Center in such a way as to institute the means of close interaction between USAMRMC/TATRC research managers and their Principal Investigators located in the Western US and Pacific Rim. Several research elements of TATRC will be expanded and assessed through the development the TATRC Western Field Office/Research Center to collaborate with west coast industry resources. This research collaboration will provide opportunities to develop more robust partnerships by leveraging the west coast industry resources with related research programs in TATRC's traditional research and development portfolios. The goal in task one will be to provide TATRC leadership with 'on the ground' expertise in the status of their Pacific/West research programs.

Accomplishments:
TATRC west coast field office helped support/facilitate the Medicine Meets Virtual Reality (MMVR) conference in January 2007. MMVR is designed as a forum for encouraging and sharing innovative research on information- based tools for clinical care and medical education.

Key Research Accomplishments

1. Design and Development of a multiple components system based on previous best-practice PACS-based architectures & clinical-tailored workflow

2. 1st design and development to comply with DICOM-RT data model object definitions w/ clinical data from PT systems

3. 1st designed ePR system to integrate data from PT systems at LLUMC

4. Centralized design for a Data Repository & Global data distribution across WAN & LAN

5. Web-based design for PT information distribution

6. Global Treatment Updates designed to provide up-to-the-minute data for patient case review

7. Open System Integration Design that will drive future PT sites & vendor markets

8. Provides infrastructure for future outcomes-related research on both longitudinal and latitudinal studies due to centralized data repository.

9. Published research work in Peer-Reviewed journals as well as accepted for presentation in International Medical Imaging Informatics conferences and Proton Therapy Symposium.

10. Hosted/Participated in various regional meetings/conferences/symposia, as consistent with TATRC's regional (programmatic, research management, and partnership-building) agenda and mandate. Examples include putting on various Product Line Reviews and assisted in Medicine Meet Virtual Reality (MMVR) Conference.

11. TATRC west coast field office helped support/facilitate the Medicine Meets Virtual Reality (MMVR) conference in January 2007. MMVR is designed as a forum for encouraging and sharing innovative research on information- based tools for clinical care and medical education.

12. Working with Dave Hood, Sr Advisor to MRMC, have participated in numerous industry meetings within California to track medical device development that have potential military application. We are also looking into additional industry associations such as Medtech Insight, OCTANe and Link that have the same purpose.

Reportable Outcomes

Accepted Related Publications and Presentations

1. Liu BJ, Huang HK, Law M, Le A, J. Documet, Gertych A, A Knowledge-Based Imaging Informatics Approach to Managing Patients Treated with Proton Beam Therapy, *Proceedings of SPIE Medical Imaging,* 6516-34:651616, 2007.
2. Accepted Oral Presentation at the SPIE Medical Imaging Conference, Feb 2007, San Diego, CA.
3. Accepted Oral Presentation at the International Syposium on Developing and Understanding a Hospital Based Proton Facility, Oct 2006, Indian Wells, CA.
4. Liu BJ, Law YY, Documet J, Gertych A, Image-Assisted Knowledge Discovery and Decision Support in Radiation Therapy Planning, *Computerized Medical Imaging and Graphics*, 31:4-5, pp. 311-321, 2007.
5. Liu BJ, A Knowledge-Based Imaging Informatics Approach for Managing Proton Beam Therapy Treatment of Cancer Patients, *Technology in Cancer Research and Treatment,* 2007. (In Press)

Conclusion

Task 1:

As a first step towards the long-term research goals and objectives, initial data models and clinical workflow models for Proton Therapy were investigated to determine the impact of integrating these new RT objects into the ePR system. A medical imaging informatics approach was applied to Proton Therapy for treatment planning of cancer patients. This methodology was utilized for the design and development of and ePR system with standardized DICOM-RT-ION data. With the ePR system and standardized data, future quantified knowledge and decision-support tools can be developed and evaluated for outcomes analysis to ultimately improve the overall patient care utilizing Proton Therapy. The following are benefits obtained from this approach and development of this standardized DICOM-RT based ePR system:

- Standardization of DICOM-RT-ION objects eliminates the challenges in assessing crucial data from proprietary PT systems.
- The DICOM-RT based ePR system can capture PT data and treatment outcomes at multiple institutions.
- Web-based for Global Utilization of Multiple PT facilities and data.
- Outcomes, treatment plans, and knowledge developed at an experienced PT facility can be captured so that future NEW PT facilities will have faster adoption, utilization, and sharing of best practice treatment course data.
- DICOM-RT-ION objects together with knowledge form a standardized and normalized platform for comparison against other treatment which utilizing the same standardized data objects.

This methodology together with the DICOM-RT based ePR system can serve as a foundation for future decision-support research and outcomes research in a new frontier of Proton Therapy.

Task 2-4:

Over the past several years the expansion of the portfolio of the Telemedicine and Advanced Technology Research Center (TATRC) managed research projects has led to significant achievements in support of the goals of the U.S. Army Medical Research and Materiel Command (USAMRMC). While this expansion has served to distribute TATRC investments both nationally and internationally, the ability to effectively leverage and bring together assets, expertise, and capabilities in the western US to develop new, cutting- edge advanced technology research and development efforts has been taxed. This award has offered a unique opportunity for the TATRC to further revolutionize military medical research in support of training and readiness, medical Command and Control, and employment of medical forces across the Department of Defense (DOD) through collaboration with the Henry M. Jackson Foundation for the Advancement of Military medicine, Inc. (HJF) in establishing the infrastructure and initial research efforts of a Western Pacific regional research center.

The HJF has provided its administrative, management and technical expertise to assist the USAMRMC/TATRC in the development of its long-term generation portfolio and investment strategy in this regional effort. The HJF's experience in facilitating medical research in support of the warfighter, as well as personnel strengths with local assets in Southern California made its capabilities uniquely valuable in support of TATRC's expanding strategic research initiatives. HJF specialists have worked closely with USAMRMC/TATRC scientists and research managers on four tasks evaluating the impact of regional management of coordinated research efforts.

Research efforts have focused on helping develop new, leading- edge research and development initiatives (e.g. embedded training) in the western US, including facilitating creation of robust, productive working relationships with nationally unique assets found only in the Pacific/West region (e.g. University of Southern California's Institute of Creative Technology). Additional military research investigations have focused on establishing proven and successful TATRC business practices, and developed new practices and methods as needed in the Pacific/West region, as well as creating a dynamic process through which to transition selected technologies from advanced research to advanced development. Under the direction of USAMRMC/TATRC, HJF has established the infrastructure (physical and personnel) of a Field Office to support the above and enhance management of existing programs and projects by enabling closer interaction between USAMRMC/TATRC research managers and their Principal Investigators.